Engineering Note
for
E906 Detector Assembly

PROJECT: E906

DOCUMENT: 1261 V4

TITLE: Station 3 Minus Drift Chamber Support

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DATE: December 12, 2011 rev 4

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ABSTRACT: This document describes the fixture used to support the Station 3 Minus (lower) drift chamber in E906.

OVERVIEW:

The station 3 Minus detector recycles drift chambers previously used on E866. The detector consists of three separate aluminum chamber frames mounted in a steel support. The chamber support sits on the SeaQuest Hall floor (See Figure 1)

This note addresses the installation of the chamber and the stand built for E906. The construction of the E866 chambers should be covered in a previous engineering note.

Each of the three chambers weighs approximately 600lbs.
Each chamber is constructed on an aluminum 6061-T6 2"x 4" C channel welded frame.
The open side of the C channel faces outward.
Figure dimensions are in inches.

DESIGN:

The support stand is constructed of ASTM A-500 2x2, 3x3 and 2x4 steel box tubing (1/4" wall thickness). The tubing is welded together to form two stand halves (see Figure 2). Each half has two beams that provide a base and a vertical section on one side. The two halves are joined with bolts where the base beams meet along the hall floor. The connected stand rests on the hall floor. The stand is secured to the concrete floor with Hilti concrete floor anchors.

An aluminum pad is placed into the aluminum C channel chamber frame at each bottom corner. The pad is connected to the chamber using a ¼-20 SHCS (McMaster Carr Part 91251A551) into an existing ¼" hole on the chamber (see figure 3 and 6).

An equipment leveling foot (McMaster Carr part 62805k41) rated for 500lbs is threaded into the pad at each bottom corner. The foot allows up to 2" height adjustment

The leveling foot rests on a ¼" A36 steel plate that is welded to the box beam support knee. The weight of the chamber is on this steel plate.

The vertical section is a tall post of 3x3 box tubing with a comb shaped weldment at the top. The machined slots making the comb are to resist movement forward/aft movement of the detector. The comb slots are located above the chamber center of gravity.

An aluminum pad is positioned on each side of the chambers. The aluminum pad is secured with a ¼-20 SHCS (McMaster Carr part 91251A551) into an existing hole on each side of a chamber. The pad center has a tapped hole for a ½-13 grade 5 bolt (McMaster Carr part 92865A738). This 5" ½-13" bolt is positioned in the comb slot. Nuts are used on each side of the comb to mark the position. The chamber position when aligned to the beam height places the bolt above the low point of the comb slot. These side pads are not intended to support chamber weight.

The E906 installation requires a 90 degree rotation of the 3 E866 chambers. The E866 lifting points were removed. New steel lifting pads are affixed. The two steel lifting pads are attached to the chamber using 3/8” bolts thru both flanges of the C channel. (see Figure 5 & 7) The lifting pads are tapped to accept a ½” hoist ring.

INSTALLATION:
The chambers are lifted vertical using the hoist rings. The leveling feet are attached. The chamber is lowered into the support so the leveling pad rests on the flat plate and the ½” bolts are located in the comb slots. Removal for service is in the reverse order.

ANALYSIS:
The center of mass for a support half is located above the knee plate (See Figures 8 & 9). The chambers are approximately symmetric with a center of mass coincident with their geometric centers. The combined center of mass for the detector assembly is 9.25” below the center of the middle chamber. These values were obtained from the assembly model in Autodesk Inventor 2010. (See figures 11 & 12)

The stand is most unstable when loaded with a single chamber in an upstream or downstream position. Using half the mass of a single chamber about the X axis direction through the center of mass of the support is:

Force about Support center of mass $X_{axis} = 300SIN(12.1) = 63lbs$
(see Figure 9)

This force is about 20% the weight of the stand half alone. The combined forces are in a downward direction at about 13 degrees from vertical. This line of force is within the base of the support. The force of a chambers center of mass along the Z direction adds to the stability of the assembly. The force about the Y direction is negligible. The detector is stable from tipping due to the chambers loading.

Knee:
The adjustable leveling feet of the 3 minus chambers rest on a ¼” steel plate. The steel plate is welded to a steel knee constructed of a horizontal 2x4” and two vertical 2x2” steel box beams. The horizontal box beam is connected to the vertical post with another 2x4” box beam.

Three chambers with a weight per side of 300lbs yield a 900lb load on each knee. The box tubing is ASTM A500 steel with minimum yield strength of 46ksi. The weld filler material used was 60XX series with allowable strength of 18ksi. The knee weldment is constructed using 3/16” fillet weld.

The analysis of the weld between the 2x4 horizontal beam in the knee weldment and the 3x3 vertical post (see Figure 10) uses Table XXI page 4-77 of the Steel Construction Manual 9th ed
The allowable load $P = CC_1Dl$

$l = 4$
$kl = 2$
$k = 0.5$
$al = 10$
$a = 2.5$
C_1 for weld filler material 60XX = 0.857
D = 3 for 3/16 weld size
C = 0.171 for a = 2.5 (interpolating table values between 2.4 & 2.6 in the table)

NOTE: using k = 0 for an out of plane load as per Special Case mentioned on Table XIX

P = (0.171)(0.857)(3)(4) = 1.76kips
The chamber load of 0.9kips at the calculated point is less than the allowable load of 1.76kips on this weld. This weld is strong enough for the load.

The analysis of the weld between the two horizontal 2x4 box beams is similar.(see figure 10) The load on this weld is approximately in the plane of the weld, but not quite. The distance from the centerline of the chamber leveling feet to the weld is approximately 0.25”
The allowable load $P = CC_1Dl$
$l = 4$
$kl = 2$
$k = 0.5$
$al = 0.25$
$a = .06$
C1 = 0.857
D = 3
C = 1.67

NOTE: using k = 0 for an out of plane load as per Special Case mentioned on Table XIX

P = ((1.67)(0.857)(3)(4) = 17kips
The chamber load of 0.9kips at the calculated point is less than the allowable load of 17kips on this weld. This weld is strong enough for the load.

The 2x4 Tee horizontal box beam (labeled in figure 10) is supported on each end by a 2x2 box beam section. The horizontal 2x4” box beam is in compression. It’s deflection under the chamber load is

$$\Delta \max = \frac{WL^3}{384EI}$$

W=300lbs per detector
L = 22in
Location of detectors at 3.5”, 11” 18.5” from one end
E = 30x10^6 lbs/in^2
I = 4.69in^4
S = 2.65in^3
$\Delta \max = 0.0002$in
The beams deflection is very small and acceptable for this application.

The 2x4 box Tee beam is welded to the short 2x2 box columns. The shear at the supported ends is calculated by summing the concentrated load at the three load points.

$$V = \Sigma \frac{Pa}{L}$$

For a = distance to the load of: 3.5, 18.5 & 11 inches
P = 300lbs
L = 22 inches

V = 48lbs + 252lbs + 150lbs = 450lbs

The weld area is = (12") (0.707)(3/16) = 1.6in^2
for a shear stress = 450lbs/1.6in^2 = 281psi.
The weld connecting the 2x4 box beam to the columns have an allowable shear stress of 18ksi. These welded connections are strong enough for this application

.

The 14.5" 2x2 columns should be considered short, as

$$\lambda = \frac{kl}{r}$$

k=2
λ=14.5

$$r = \sqrt{\frac{bd^3 - b_1 d_1{}^3}{12A}}$$

b=2
d=2
b1=1.5
d1=1.5
A=bd-b1d1 = 4-(1.5^2) = 1.75in^2
R = 0.7217

$$\lambda = \frac{(2)(14.5)}{0.7217} = 40$$

The slenderness ratio can be found

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$$

E = $3x10^4$ ksi
$F_y = 46ksi$
$C_c = 118$

$\lambda < C_c$, 40 < 118 so the column is short

The allowable stress for such a column is found:

$$F_a = \frac{\left[1 - \frac{\left(\frac{Kl}{r}\right)^2}{2C_c^2}\right] F_y}{F.S.}$$

F.S. safety factor = $\frac{5}{3} + \frac{3\left(\frac{Kl}{r}\right)}{8C_c} - \frac{\left(\frac{KL}{r}\right)^3}{8C_c^3}$ = 1.6628

$F_a = 26.07 ksi$ = allowable stress on the 2x2 column.

The loads on the knee create stresses below the allowed values. The knee structure is adequate for supporting these chambers

Comb:
The comb is a ½" steel plate weldment with slots machined in the vertical plate to accept the chamber side locating bolts. (See figure 2) The slotted plate is welded perpendicular to a base plate. The two are braced using a 4 x 6" plate on each end. The welds are 3/16" filets.

The comb is welded to the top of the 3x3 vertical post. The weakest point on this weldment is the connection of the comb box to this post. The analysis of this eccentric weld uses Table XXI page 4-77 of the Steel Construction Manual 9th ed.
The allowable load P = CC_1Dl (see Figures 1 & 2 for dimensions)

l = 3
kl = 3
al = 7.5
a =2.5
C_1 = weld filler material 60XX = 0.857
D = 3 for 3/16 weld size
K = 1
C = 0.171 for a = 2.5 - using column 0 for an out of plane load, interpolating table values
P = (0.171)(0.857)(3)(3) = 1.32kips

The slots in the comb are 0.0531" in width and approximately 57" from the knee plate. A ½" locating bolt will allow a vertical chamber to tilt Tan^{-1}(.0.031/57) = 0.031 degrees in the slot.

Half the chamber weight of 300lb will place a side load on one bolt of
= 300lbs SIN (0.031) = 0.16lbs.

The three chambers have a maximum combined horizontal load on the comb of:

*	Fz = 3 x 0.16lbs = 0.48lbs
The three chambers aligned as described above have no vertical load on the comb.
The welds attaching the comb to the vertical post are adequate.

This load on the 5” bolt places a stress on the aluminum pad and chamber C channel.
Stress at pad (using circular cross section modulus) is

$$= \frac{M}{S} = \frac{(0.016 lbs)(5 in)}{(098175)(0.5 in)^3} = 0.65\, psi$$

The force on the pad = 65psi / 0.19625in^2 = 13lbs

The fastener hardware is grade 5 with tensile strength of 180ksi. The allowable shear strength should be 17% of tensile strength for 30ksi. The aluminum pad and chamber are 6061-T6 with allowable shear stress of 14ksi. The forces on welds and these components are small and well below the allowable shear strengths of the welds, fasteners, steel or aluminum. The side supports are strong enough for the expected loads.

Rigging pads:
A 1” thick steel lifting pad of A36 steel is affixed to the top corners of each detector. The aluminum 4x2 C channel has two holes through both 0.25”flanges.(see Figure 4 & 5) The rigging pad is attached using two 3/8-16 SHCS bolts (McMaster Carr part 91251A651) Grade 8 steel and conforms to ASTM A574. The bolts have a tensile strength of 180ksi. Using an allowable shear of 17%F_u=30.8ksi as per ASD 9th ed. table I-D.

The sheer load on each bolt
300lbs/2 = 150lbs
Tensile stress area for 3/8-16 fastener = 0.0775in^2
Shear load = 150lbs/0.0775in^2 = 1935psi

Tear out of aluminum C channel (see Figure 4)
2x4 6061-T6 aluminum C channel minimum yield strength = 35ksi
Load on a 0.397 hole = 150lbs
Effective cross sectional area
Area = (2 flanges)(0.884in)(2)(0.25 thickness) = 0.884in^2
Shear on hole = 150lbs/0.884 = 170psi

Tear out of the rigging pad (See figure 7)
Steel rigging pad A36 steel with minimum yield strength of 36ksi
Load on a 0.397 hole = 150lbs
Effective cross sectional area (0.53)(2)(3.5) = 3.71in^2
Shear on hole = 150/3.71 = 40.4 psi.

The shear load on the bolts and channel are within acceptable limits, the pad and the aluminum C channel are adequate to secure the lifting pads.

Hoist rings:

The ½-13 hoist rings used to lift the aluminum C channel framed chamber vertical are also used to lift the assembly and place it on the stand. Each hoist ring supports approximately 300-lbs. The area of a ½-13 bolt, based on a minor diameter of 0.4041-in^2, is 0.128-in^2 and the resulting shear stress in each eyebolt is 300/0.128 = 2344psi. We have identified swivel eyebolts made from forged alloy steel type AISA-SAE 4140 (American Drill Bushing, part number 33515) with a minimum tensile strength of 180ksi. These bolts are certified for a work load limit of 2500-lbs with a pivot range of 180 degrees and a swivel range of 360 degrees and are suitable for this application.

Seismic loading:

The detector assembly is secured to the hall concrete floor using 3/8" Hilti HDI Drop-In concrete anchors at each corner. It is understood that the SeaQuest hall concrete floor can be rated at 4000psi. The Hilti design guide lists the selected anchors as having allowable load ratings of 1115lbs in tension and 1250lbs for shear in 4000psi concrete. (See Figure 13 for free body diageam)

Total weight = (3)(600) + (2)(286) = 2372 lbs
Seismic Loading = 15% (2372) = 356 lbs

Height of assembly center of gravity = 54.8in
Looking at seismic loading in the positive direction:

$$\Sigma F_x = 0 = R_{AX} + 356lbs$$
$$R_{AX} = -356lbs$$

$$\Sigma F_Y = 0; \qquad 0 = R_{AY} + R_{BY} - 900lbs - 286lbs \qquad (1)$$
$$\Sigma M_A = 0 = 900lbs(13in) + 286lbs(8.7in) - 356lbs(54.75in) - R_{BY}(54.25)$$
$$0 = 11700inlbs + 2488.2inlbs - 19491inlbs - R_{BY}$$
$$R_{BY}(54.25in) = -5302.8inlbs$$
$$R_{BY} = -97.75lbs$$

Substituting into (1)

$$R_{AY} = 1283.75lbs$$

If the seismic force is directed in the negative direction, then

$$\Sigma F_x = 0 = R_{AX} - 356lbs$$
$$R_{AX} = 356lbs$$

$$\Sigma F_Y = 0; \qquad 0 = R_{AY} + R_{BY} - 900lbs - 286lbs \qquad (2)$$

$$\Sigma M_A = 0 = 900lbs(13in) + 286lbs(8.7in) + 356lbs(54.75in) - R_{BY}(54.25)$$

$$0 = 11700inlbs + 2488.2inlbs + 19491inlbs - R_{BY}$$

$$R_{BY}(54.25in) = 33679.2inlbs$$

$$R_{BY} = 620.8lbs$$

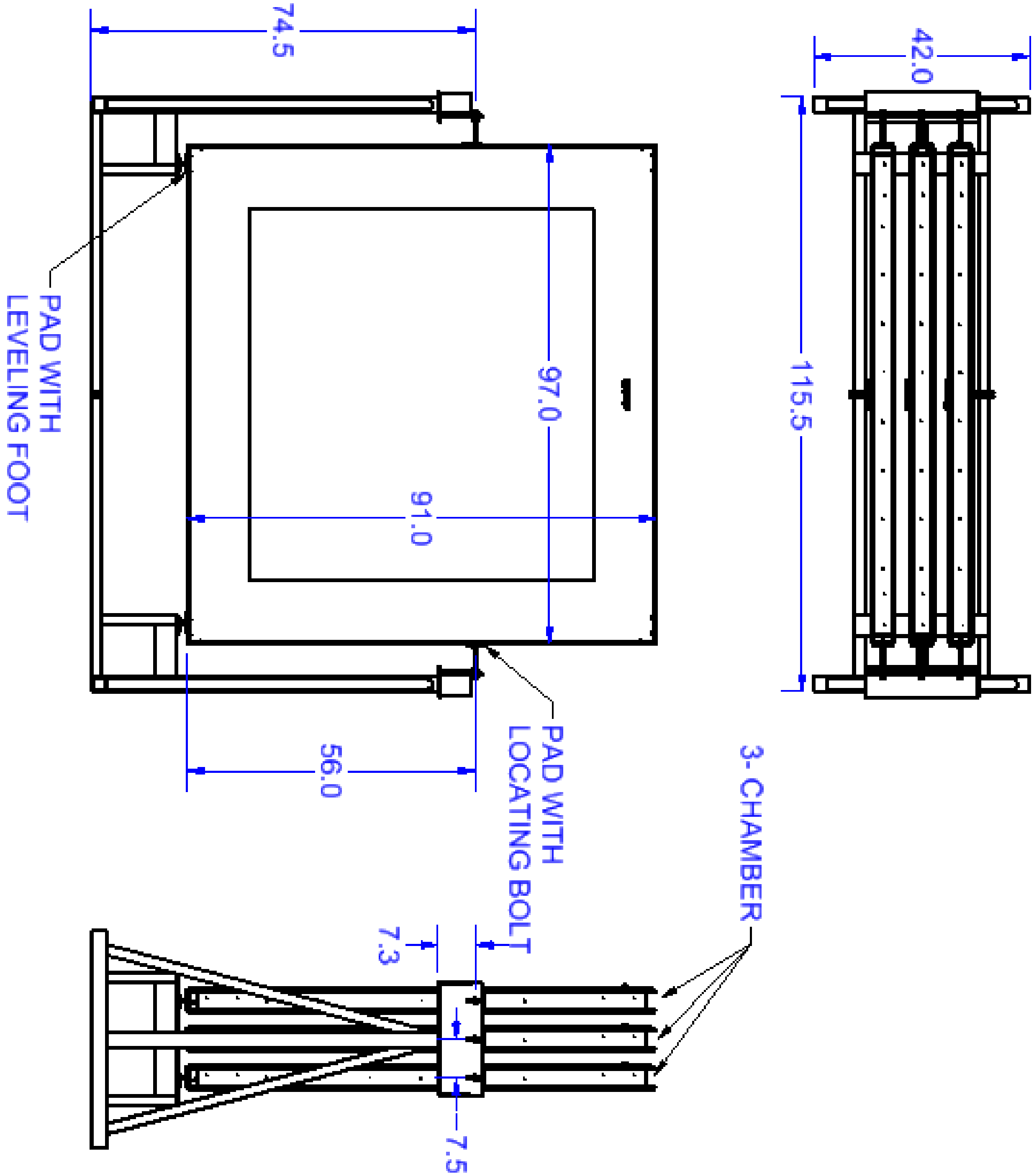
Substituting into (1)

$$R_{AY} = 565.2lbs$$

With a Hilti anchor at each corner, the shear load on each Hilti anchor has a value of 178lbs. This value is well below the allowable maximums of 1250lbs. The compression of the anchors is within the specification of the concrete floor.

The two detector stand halves are connected at the center by four 3/8" grade 5 bolts. The seismic loading creates a shear load of 98lbs on these four bolts. The single bolt load is 24.5 lbs, (using a tensile stress area of 0.0775in^2) resulting in a shear stress of 316psi. This is well below the allowable shear stress of 36.8ksi.

The detector is well secured for the calculated seismic activity.



74.5
42.0
PAD WITH
LEVELING FOOT
97.0
91.0
115.5
56.0
PAD WITH
LOCATING BOLT
3- CHAMBER
7.3
7.5

Figure 1

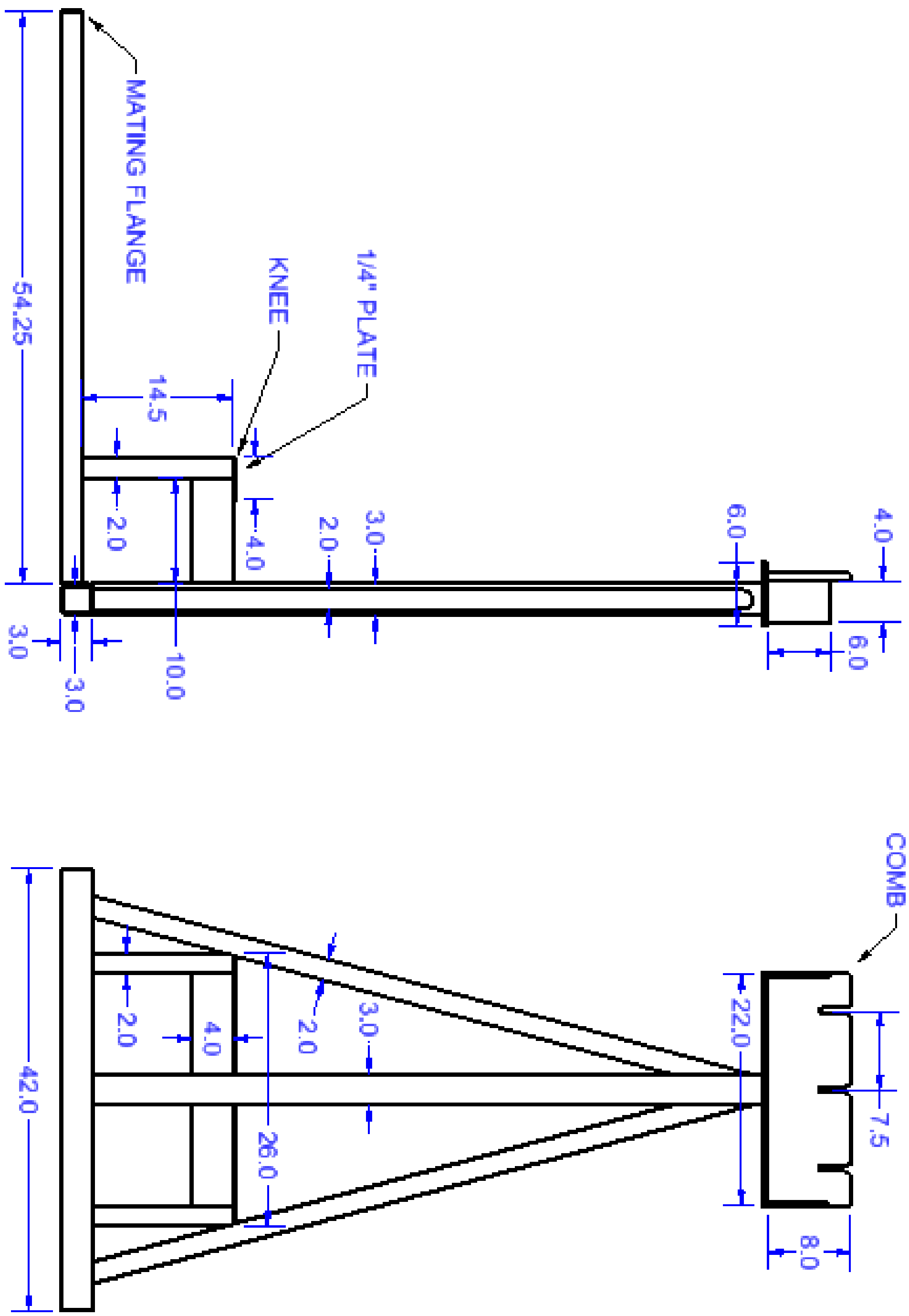

MATING FLANGE
54.25
14.5
KNEE
1/4" PLATE
2.0
4.0
2.0
3.0
6.0
4.0
3.0
3.0
10.0
6.0
COMB
42.0
2.0
4.0
2.0
3.0
26.0
22.0
7.5
8.0

Figure 2

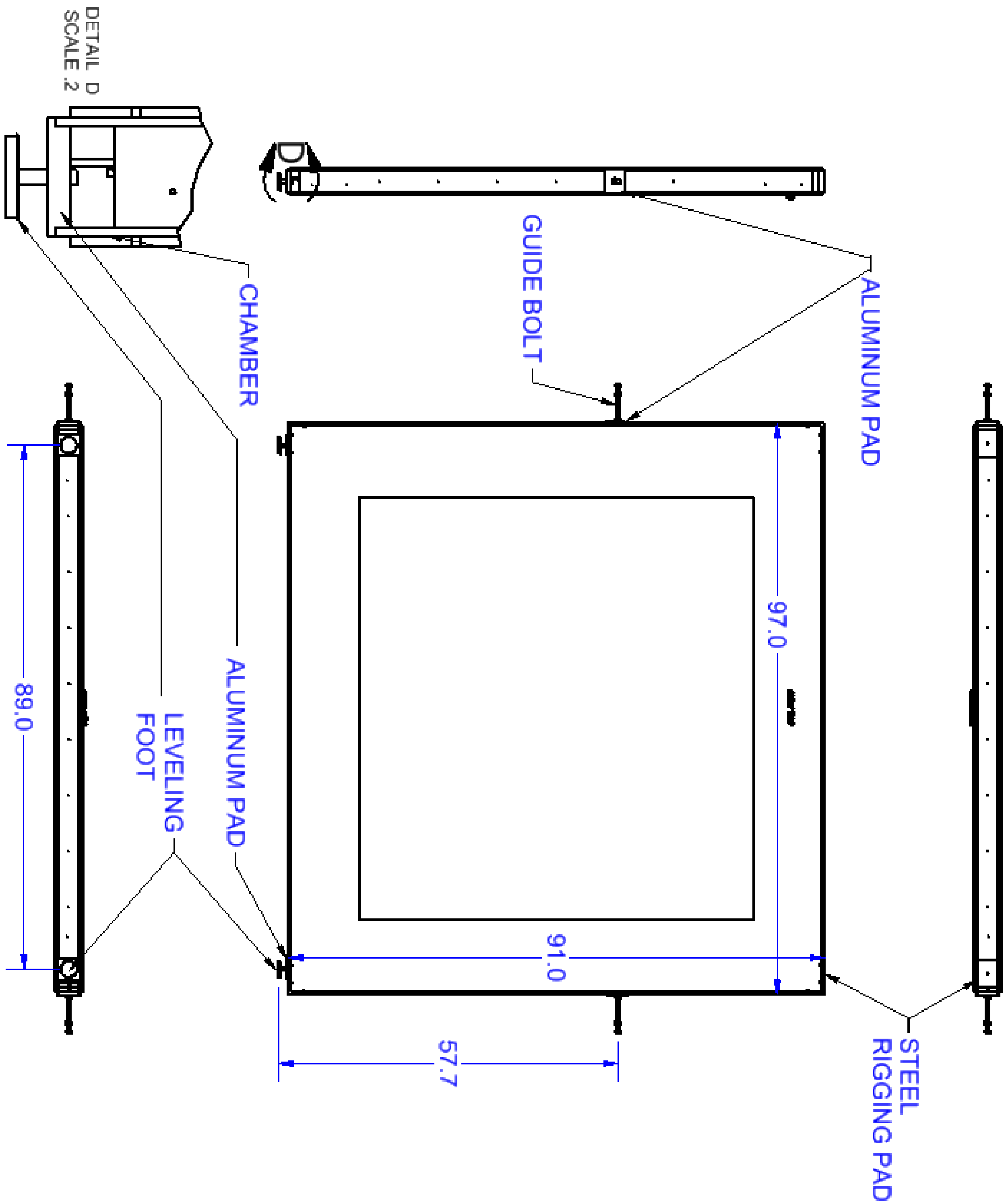

DETAIL D
SCALE .2
D
GUIDE BOLT
ALUMINUM PAD
CHAMBER
ALUMINUM PAD
LEVELING FOOT
89.0
97.0
91.0
57.7
STEEL RIGGING PAD

Figure 3

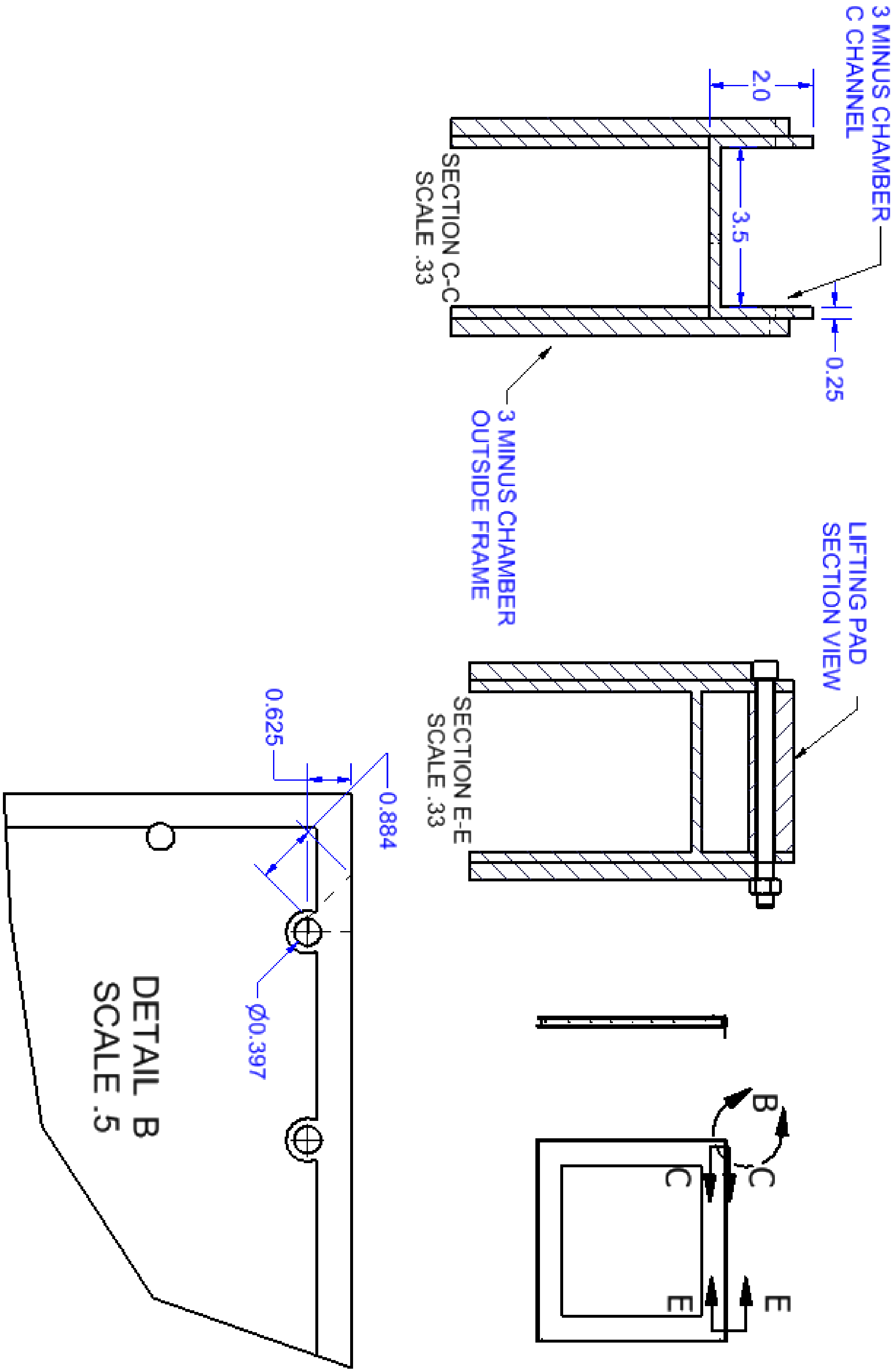

3 MINUS CHAMBER
C CHANNEL
2.0
3.5
0.25
SECTION C-C
SCALE .33
3 MINUS CHAMBER
OUTSIDE FRAME
LIFTING PAD
SECTION VIEW
SECTION E-E
SCALE .33
B
C
C
E
E
0.625
0.884
Ø0.397
DETAIL B
SCALE .5

Figure 4

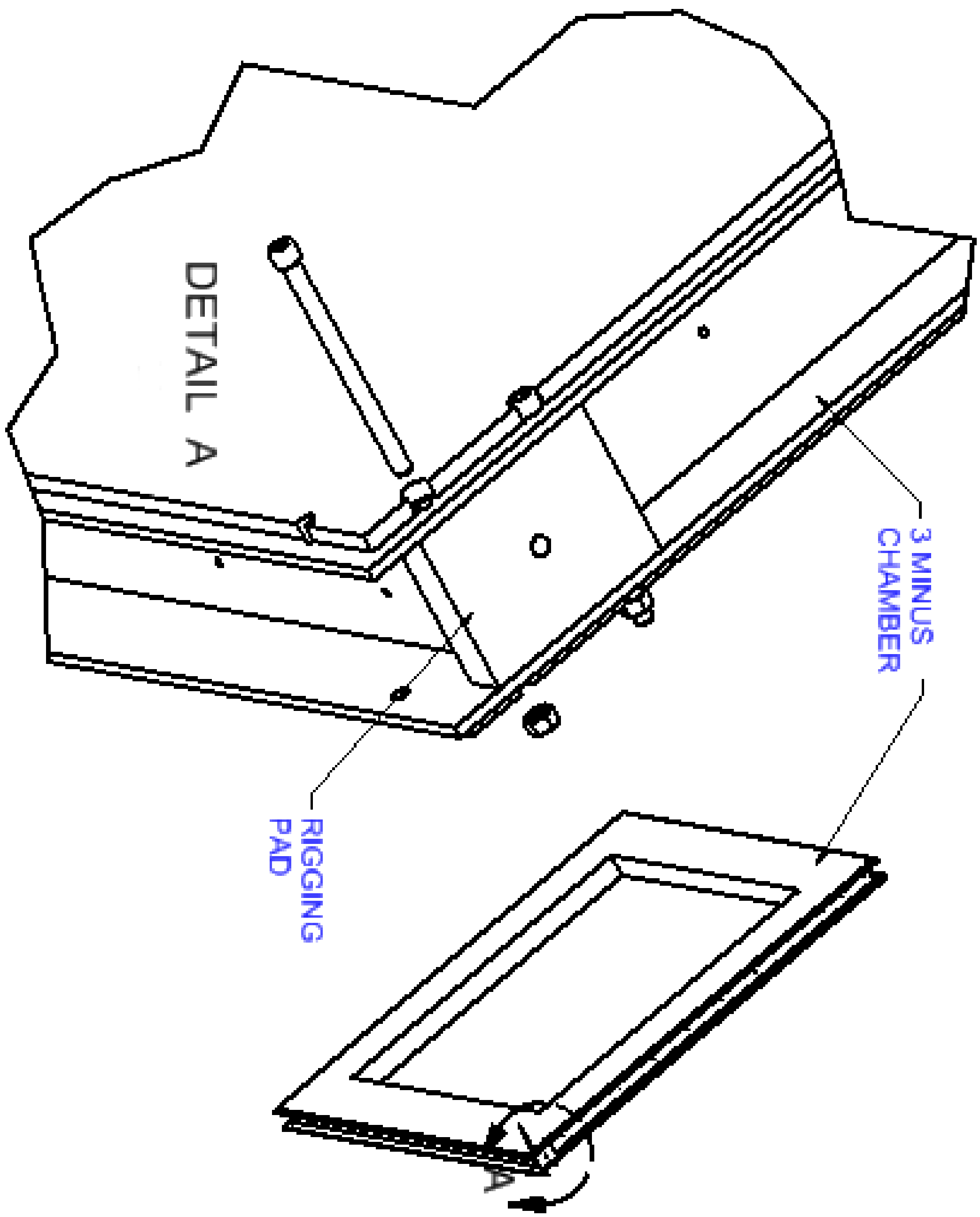


Figure 5

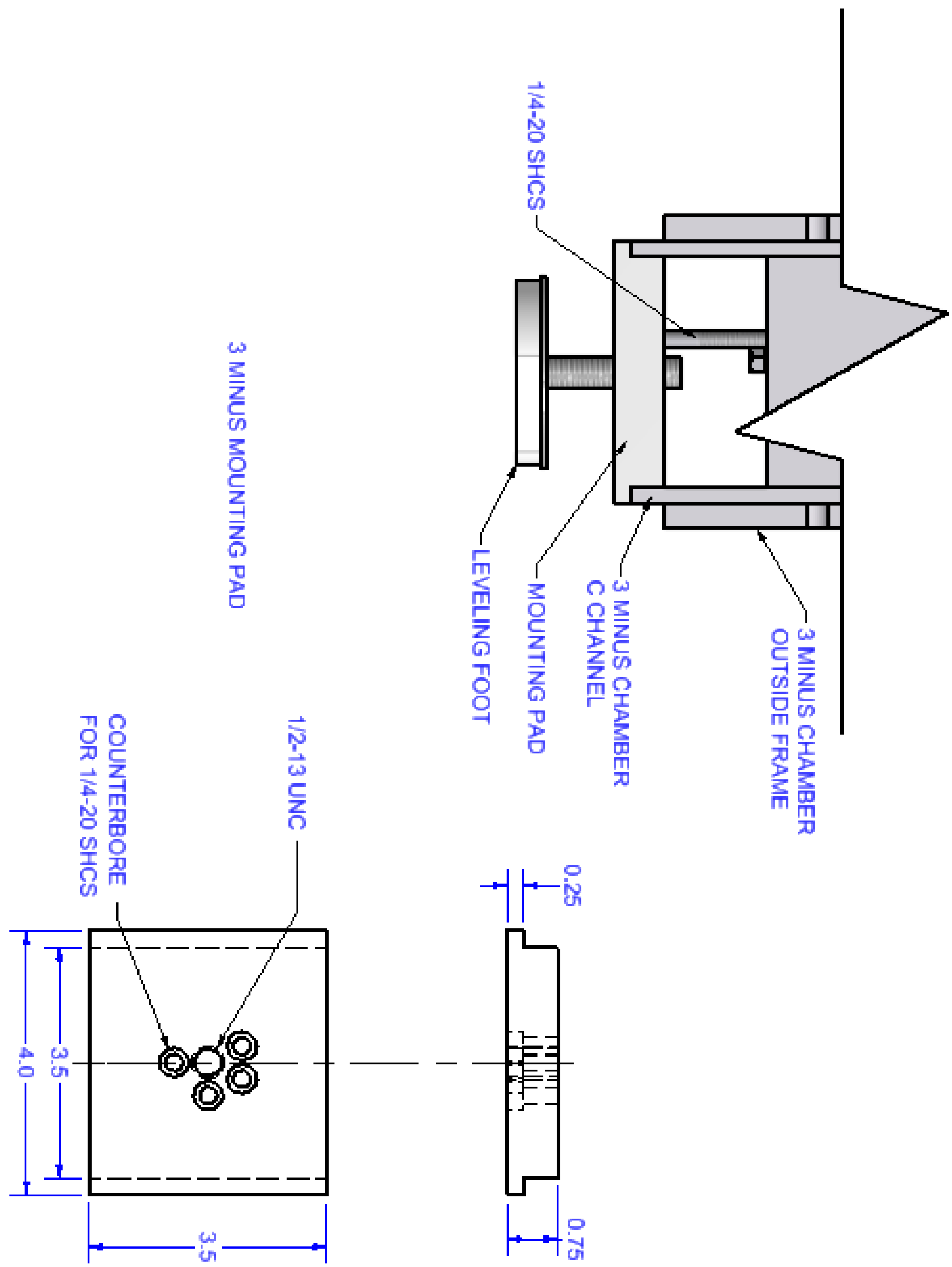

1/4-20 SHCS
3 MINUS CHAMBER OUTSIDE FRAME
3 MINUS CHAMBER C CHANNEL
MOUNTING PAD
LEVELING FOOT
3 MINUS MOUNTING PAD
1/2-13 UNC
COUNTERBORE FOR 1/4-20 SHCS
0.25
0.75
4.0
3.5
3.5

Figure 6

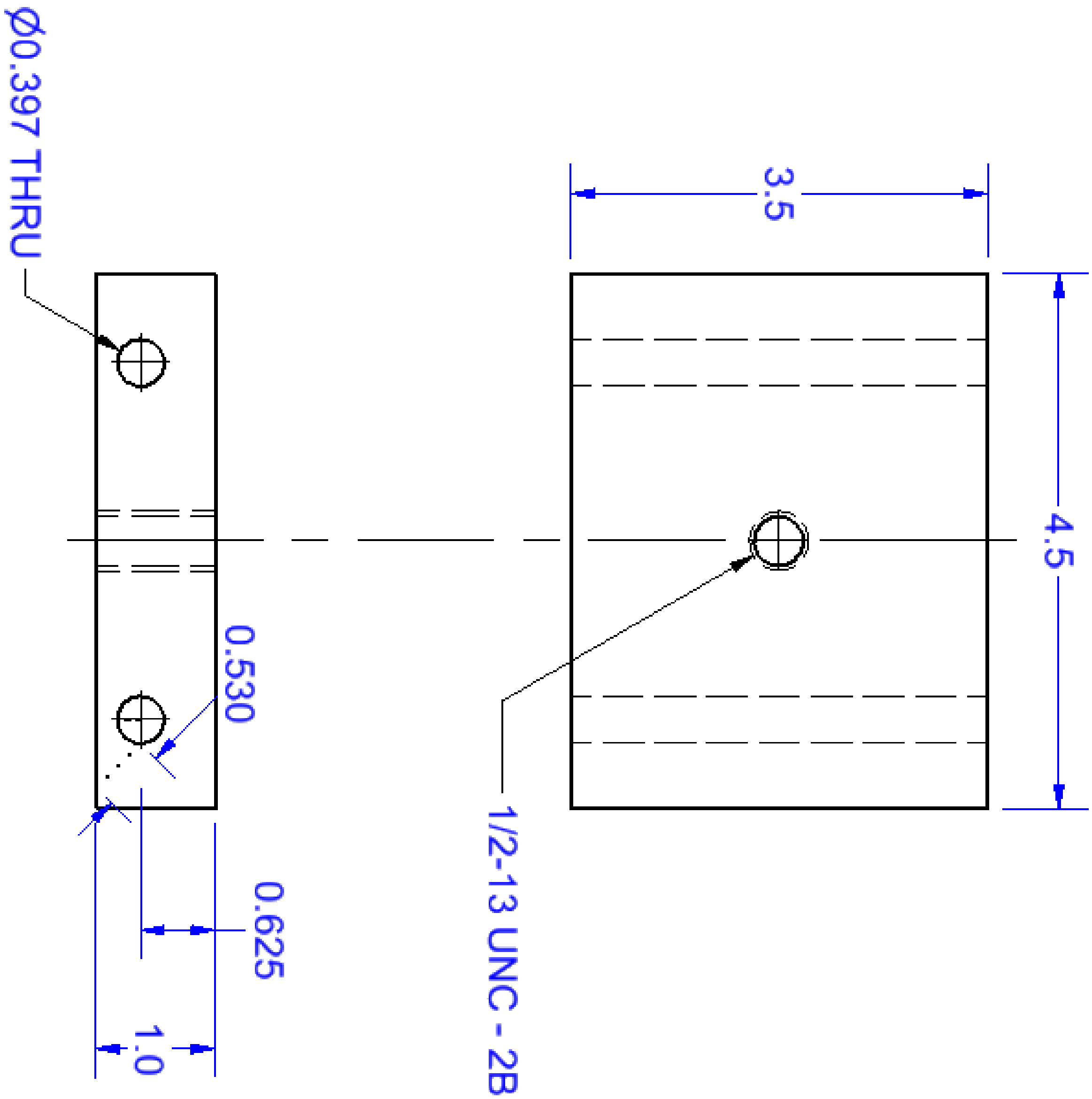


Figure 7

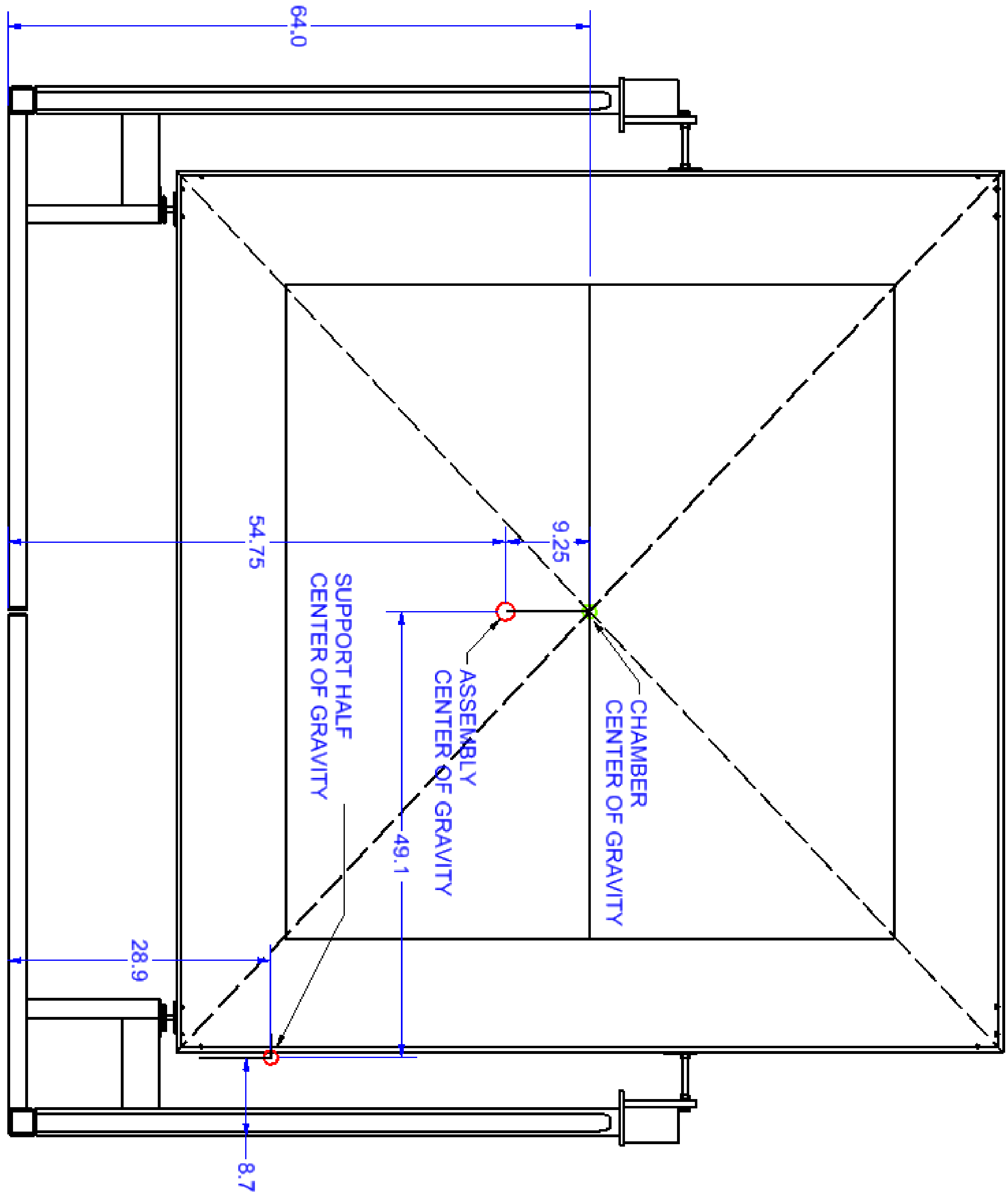

64.0
54.75
9.25
SUPPORT HALF
CENTER OF GRAVITY
ASSEMBLY
CENTER OF GRAVITY
CHAMBER
CENTER OF GRAVITY
49.1
28.9
8.7

Figure 8

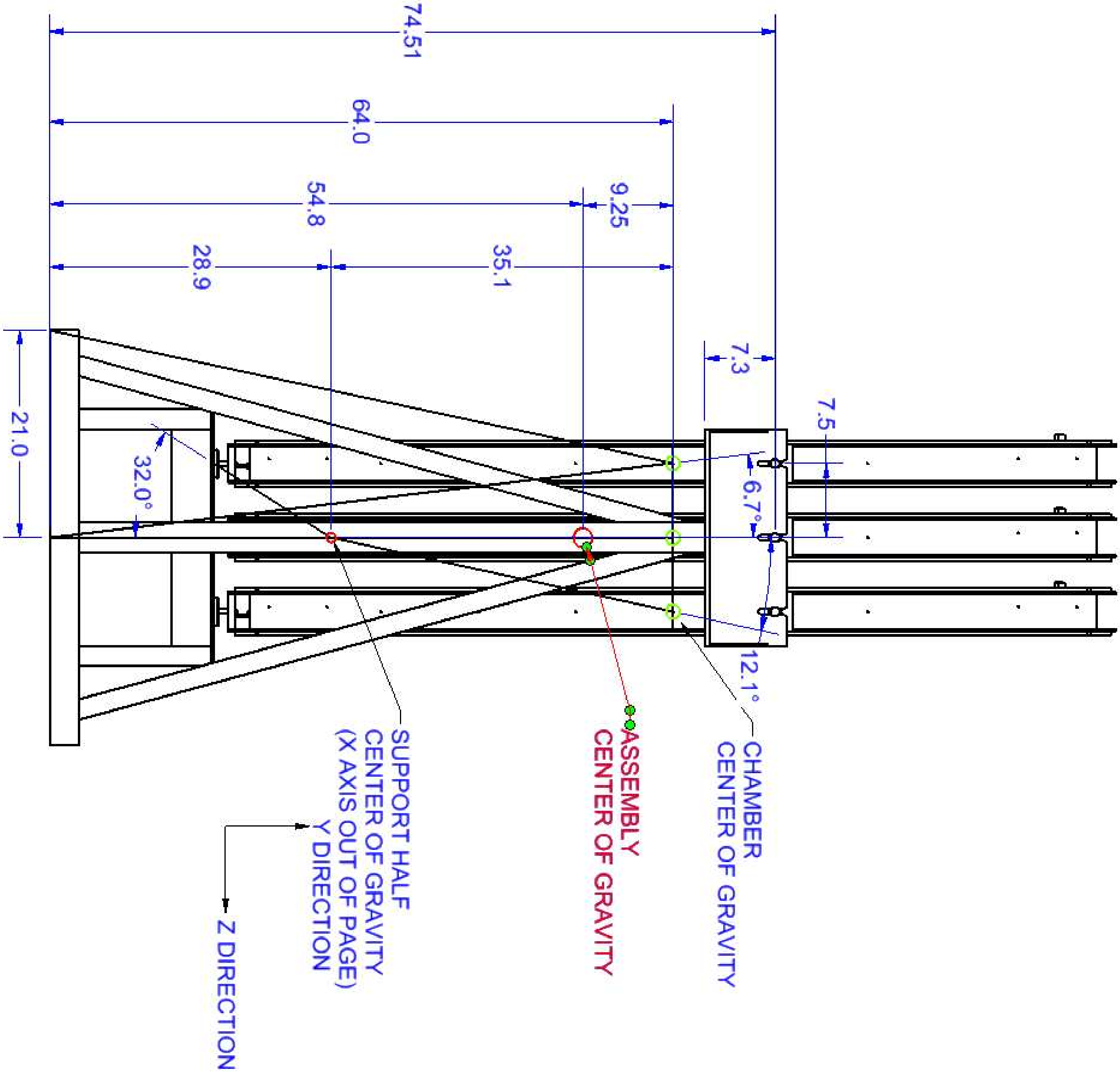

74.51
64.0
54.8
9.25
28.9
35.1
7.3
7.5
21.0
32.0°
6.7°
12.1°
CHAMBER
CENTER OF GRAVITY
ASSEMBLY
CENTER OF GRAVITY
SUPPORT HALF
CENTER OF GRAVITY
(X AXIS OUT OF PAGE)
Y DIRECTION
Z DIRECTION

Figure 9

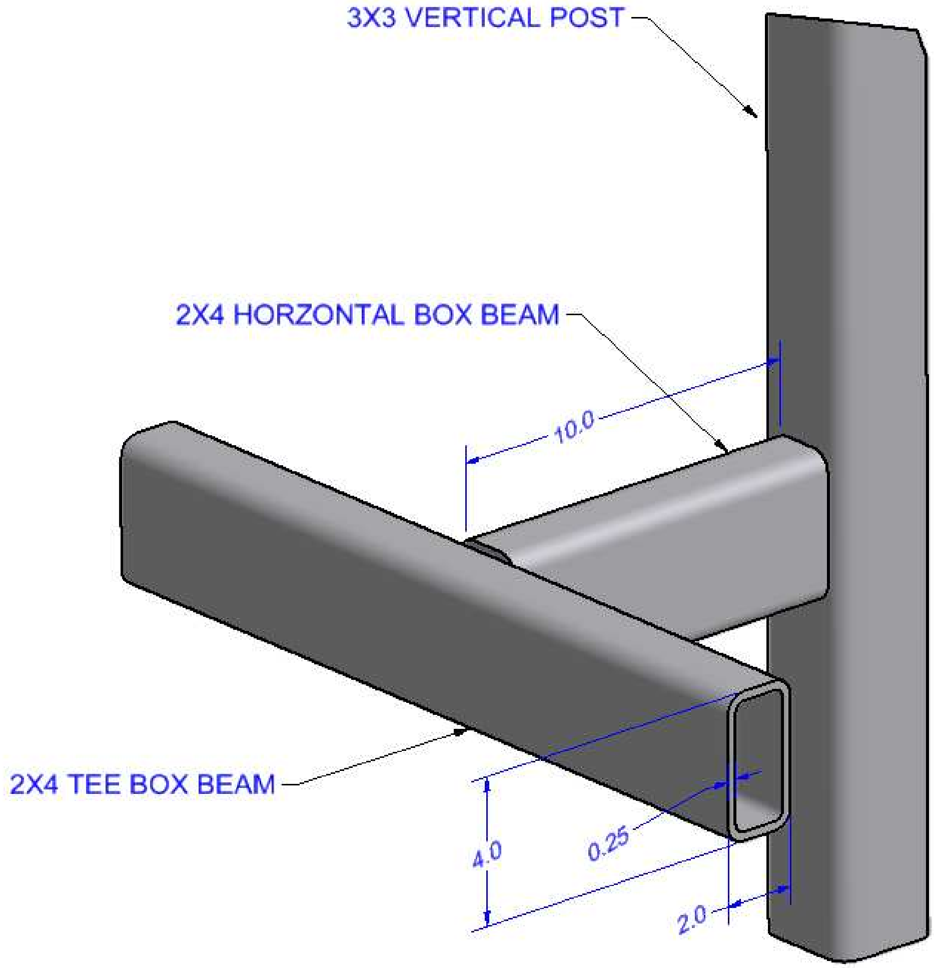

3X3 VERTICAL POST
2X4 HORZONTAL BOX BEAM
10.0
2X4 TEE BOX BEAM
4.0
0.25
2.0

Figure 10

Physical Properties for 3minus_box_stand
From Autodesk Inventor 2010
General Properties:
Material: {Steel}
Density: 7.860 g/cm^3
Mass: 286.241 lbmass (Relative Error = 0.000047%)
Area: 7282.992 in^2 (Relative Error = 0.000011%)
Volume: 1008.029 in^3 (Relative Error = 0.000047%)
Center of Gravity:
X: 0.000 in (Relative Error = 0.000047%)
Y: 28.915 in (Relative Error = 0.000047%)
Z: -8.648 in (Relative Error = 0.000047%)

Figure 11

Whole Assembly
Physical Properties for 3minus_chamber_support
From Autodesk Inventor 2010

General Properties:
Material: {}
Density: 3.265 g/cm^3
Mass: 2172.745 lbmass (Relative Error = 0.000096%)
Area: 78310.890 in^2 (Relative Error = 0.000035%)
Volume: 18420.486 in^3 (Relative Error = 0.000096%)
Center of Gravity:
X: -0.009 in (Relative Error = 0.000096%)
Y: -9.272 in (Relative Error = 0.000096%)
Z: -0.00 in (Relative Error = 0.000096%)

Figure 12

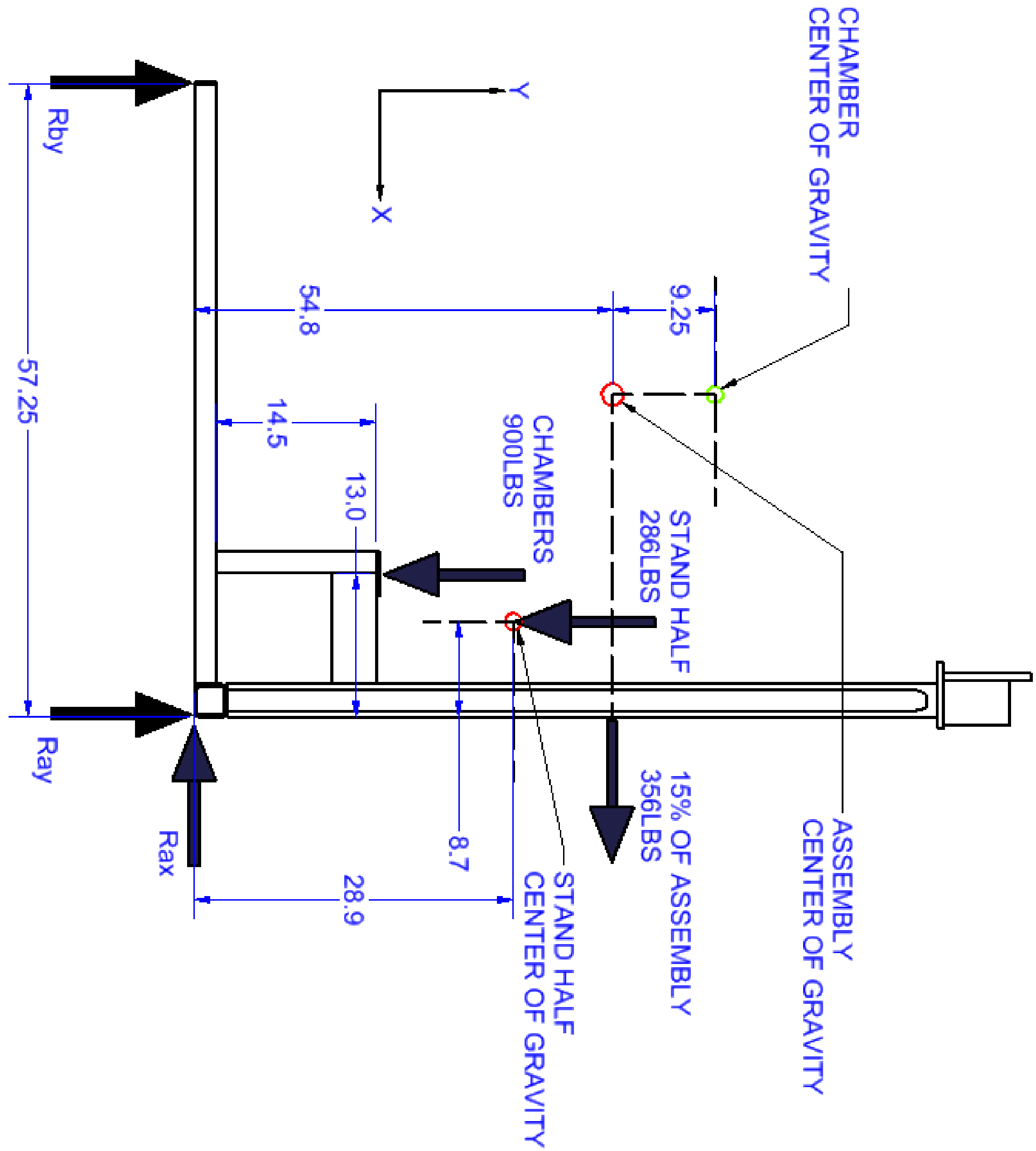

CHAMBER
CENTER OF GRAVITY
Y
X
Rby
54.8
9.25
57.25
14.5
13.0
CHAMBERS
900LBS
STAND HALF
286LBS
15% OF ASSEMBLY
356LBS
ASSEMBLY
CENTER OF GRAVITY
Ray
Rax
8.7
28.9
STAND HALF
CENTER OF GRAVITY

Figure 13